STUDIES IN PHOSPHORUS CHEMISTRY

BY

RALPH GHER, JR.

A.B., University of Illinois, 1948
M.S., University of Illinois, 1949

AN ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN
CHEMISTRY IN THE GRADUATE COLLEGE
OF THE UNIVERSITY OF ILLINOIS, 1952

URBANA, ILLINOIS

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ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Professor L. F. Audrieth for his advice and guidance throughout the course of his graduate work.

He is grateful to the Victor Chemical Works for sponsoring the fellowship which enabled him to undertake this investigation.

The generous assistance of Dr. Howard Adler, Dr. W. H. Woodstock, Dr. R. N. Bell and Dr. A. D. F. Toy of the Victor Chemical Works in furnishing special chemicals and information is acknowledged with gratitude.

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STUDIES IN PHOSPHORUS CHEMISTRY

PART I

Sodium Tetrametaphosphate

INTRODUCTION

The modern method for the preparation of tetrametaphosphate is based upon the work of Bell, Audrieth, and Hill[1] who prepared tetrametaphosphoric acid by the low temperature hydration of phosphorus (V) oxide. However, sodium tetrametaphosphate prepared in this manner had not been proven to be identical with that obtained by earlier workers. Discrepancies in x-ray data reported by various investigators[2, 3] made comparison impossible. It was therefore considered desirable to prepare the tetrametaphosphate both by the above procedure and by the older thermal dehydration method so that positive identification might be achieved by direct comparison.

EXPERIMENTAL

Sodium tetrametaphosphate was prepared by the high temperature dehydration procedure representing a modification of the older Warschauer[4] method by Andress,[5] in accordance with the following equations:

$$Cu(NO_3)_2 \cdot 3H_2O + 2H_3PO_4 \longrightarrow Cu(H_2PO_4)_2 + 2HNO_3 + 3H_2O$$

$$2Cu(H_2PO_4)_2 \xrightarrow{420^\circ} Cu_2(PO_3)_4 + 4H_2O$$

$$Cu_2(PO_3)_4 + 2Na_2S \longrightarrow Na_4(PO_3)_4 + 2CuS$$

Sodium tetrametaphosphate, prepared by neutralization of the low temperature hydration product of phosphorus (V) oxide, was obtained from the Victor Chemical Works.

Both materials, when subjected to crystallization from aqueous solutions under appropriate conditions were found to give the low and high temperature modifications of the 4-hydrate. Dehydration of the 4-hydrates resulted in the formation of identical anhydrous salts. Positive identification was made possible by a complete study of the x-ray diffraction patterns of all samples, demonstrating that the tetrametaphosphate prepared by the more convenient low temperature hydration procedure is the same as the products prepared heretofore by less efficient methods.

Attempts were made to define more precisely the relationships between the two crystalline modifications of the 4-hydrate. The high temperature form is easily prepared by crystallization from warm aqueous or alcoholic solutions or by allowing the so-called low temperature form to stand in contact with a saturated solution of the compound at room temperature or above.

The so-called low temperature modification appears to be metastable with respect to the high temperature form. The low temperature 4-hydrate is easily converted to the high temperature form, but the reverse process has not been shown to take place. Crystallization even at low temperatures (0 to −7° C) usually results in the formation of the high temperature form or, at best, in a mixture of the two forms. It is significant, however, that crystallization by the addition of acetone to an aqueous solution of the salt results in the formation of the almost pure low temperature form.

PART II

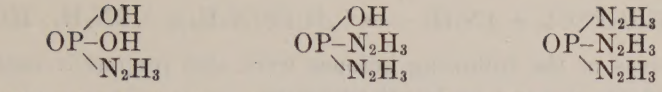
The Hydrazides of the Aryl Phosphoric and Phosphonic Acids

INTRODUCTION

The surprising biological activity of certain organic derivatives of the phosphoric and polyphosphoric acids has stimulated a tremendous amount of research in the field of organo-phosphorus compounds designed not only to develop new and useful economic poisons, but also to correlate biological activity with chemical structure. The introduction of hydrazine into the phosphoric acid molecule as replacement for the hydroxyl group would seem to represent a modification of structure not yet considered in connection with enhancement of biological activity. The similarity in structure of the resulting P-N-N group to the known toxiphoric groups, S-N-N and C-N-N, suggested that the hydrazides and hydrazones of the alkyl and aryl phosphoric and phosphonic acids should be toxiphoric.

HISTORICAL

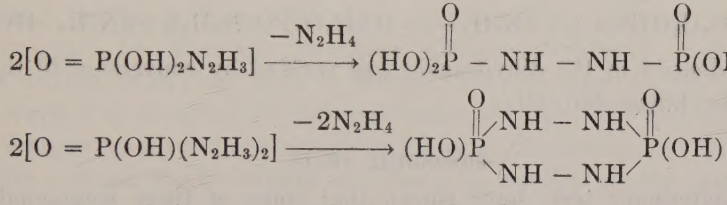
Theoretical, it should be possible to prepare compounds derived from the mono-, di-, and trihydrazides of phosphoric acid whose formulas are given below:



Phosphoric Acid Monohydrazide | Phosphoric Acid Dihydrazide | Phosphoric Acid Trihydrazide

Derivatives of monohydrazido and dihydrazido phosphoric acid, as well as the N-substitution derivatives of phosphoryl trihydrazide have been prepared, although the parent substances have not been isolated.

Related to the mono- and dihydrazido phosphoric acids are a number of compounds which can be regarded as desolvation products of each of these classes of substances, as for example:



EXPERIMENTAL

The compounds listed below have been synthesized: A. Diphenyl phophoric acid hydrazide, $(C_6H_5O)_2PON_2H_3$, was prepared by hydrazinolysis of the chloride in alcoholic solution, [equation (1)].

(1) $(C_6H_5O)_2POCl + 2N_2H_4 \longrightarrow (C_6H_5O)_2PON_2H_3 + N_2H_4 \cdot HCl$

A number of aldehyde and keytone derivatives were synthesized, a) to verify the existence of the parent compound, and b) to determine the effect of these substituents on the biological activity of the hydrazide. Derivatives of the following were prepared: benzaldehyde, p-hydroxybenzaldehyde, salicylaldehyde, anisaldehyde, acetone, p-chloroacetophenone, cyclohexanone, and acetylacetone.

The hydrazi derivative, $(C_6H_5O)_2OPNHNHPO(OC_6H_5)_2$, was prepared by the condensation reaction between the hydrazide and the chloride according to equation (2).

(2) $(C_6H_5O)_2PON_2H_3 + ClPO(OC_6H_5)_2 \longrightarrow$
$(C_6H_5O)_2OPNHNHPO(OC_6H_5)_2 + HCl$

B. Phenyl thionophosphonic acid dihydrazide, $C_6H_5PS(N_2H_3)_2$ was prepared by hydrazinolysis of the chloride in anhydrous chloroform, [equation (3)].

(3) $C_6H_5PSCl_2 + 4N_2H_4 \longrightarrow C_6H_5PS(N_2H_3)_2 + 2N_2H_4 \cdot HCl$

Derivatives of the following ketones were also prepared: acetone, p-chloroacetophenone, and cyclohexanone.

The dihydrazide gives indication of weakly basic character. The mono-picrate and a hydrochloride were prepared but analytical results for the latter compound were not too satisfactory. A di-N-carbethoxy derivative, $C_6H_5PS[NHNHCO(OC_2H_5)]_2$, was prepared by treatment of the dihydrazide with ethylchlorocarbonate.

C. Phenyl phosphoric acid dihydrazide, $(C_6H_5O)PO(N_2H_3)_2$, was prepared by hydrazinolysis of the chloride in anhydrous ether followed by repeated recrystallizations from absolute ethanol, [equation (4)].

(4) $(C_6H_5O)POCl_2 + 4N_2H_4 \longrightarrow (C_6H_5O)PO(N_2H_3)_2 + 2N_2H_4 \cdot HCl$

The identity of the dihydrazide was verified by conversion to the di-benzylidene derivative.

BIOLOGICAL TESTS

Preliminary tests have shown that some of these compounds possess biological activity. Diphenyl phosphoric acid hydrazide and its p-hydroxybenzaldehyde derivative possess tuberculostatic activity. These compounds also possess some fungicidal activity. The phenyl thionophosphonic acid dihydrazide is also toxic and has been shown to possess some hormonal activity on plants.

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VITA

The author was born in Urbana, Illinois on March 30, 1925. His elementary and secondary education was received in the public schools of that city; he was graduated from Urbana High School in June, 1943. As a member of the Navy V-12a program he attended Newberry College, Newberry, South Carolina, from July, 1943 to March, 1944. He then entered the Navy V-5 program for aviation cadet training. He was discharged from service as Aviation Cadet on September 28, 1945. He entered the University of Illinois in October of the same year and was awarded the degree of Bachelor of Arts in June, 1948. Immediately thereafter he entered the Graduate College of the University of Illinois. From June, 1948, to August, 1950, he held the position of Research Assistant on the University of Illinois Rare Earth Research Program sponsored by the Office of Naval Research. He served as teaching assistant in the Department of Chemistry from September, 1950, to June, 1951. In September, 1951, he was awarded the Victor Chemical Works Fellowship, which he held until the completion of his thesis research in June, 1952.

The author is a member of the American Chemical Society, Sigma Xi, Phi Lambda Upsilon, Alpha Chi Sigma, and Phi Gamma Delta.